

TREES TO AVOID OR TREES TO SUPPORT THE USE OF FERTILIZERS ON CROPS?

Breman H^{1*}

(1) AgroBioAfrica. Terwolde, The Netherlands

*Corresponding author: henkbreman@gmail.com

Abstract

Agroforestry is often promoted as a production system for which fertilizer use can be avoided. Indeed, a limited number of systems exist where the presence of trees in the field increases crop production, without the use of fertilizers. In general, however, the presence of trees among crops causes a reduction in crop production (30% lower on average). This paper presents a system developed in Africa, in which trees improve crop production thanks to improvement of the fertilizer use efficiency. For farmers in sub-Saharan Africa, interested in agroforestry for producing staples, trees supporting the use of fertilizers should be promoted. It is also a cheap alternative for otherwise very expensive erosion control investments.

Keywords: agroforestry; competition; fertilizer use efficiency; cost; benefit

Agroforestry, too often wishful thinking

Agroforestry is mainly promoted and introduced in sub-Saharan Africa by foreign organizations. The promise is higher and more sustainable crop production without the otherwise required (increased) use of chemical fertilizers. The author wonders if examples exist where farmers continue using the promoted approach after the end of the supporting projects.

The presence of trees in cropland leads, indeed, to a higher total phytomass production. But in-depth knowledge and experience as well as extra labor is required for using trees to increase crop production. On average, cereal crops produce about 30% less in agroforestry systems than on comparable fields without trees. The indirect positive effect of trees is usually lower than the direct negative effect of competition with crops for nutrients, water, and light. Size and form of trees enable them to intercept more light. They use part of the light otherwise absorbed by the crops.

Even more than the use of wood for heating and construction, it is the dominance of trees over crops as competitor for light, nutrients and water that is at the basis of the disappearance of trees under influence of population growth. Too often, this aspect is entirely neglected when promoting agroforestry. This is a serious error. Cases where trees have a positive effect on crop production include:

- Crops and trees that grow and develop at least partially in different seasons. For example in case of the *Faidherbia albida* production system in sub-Saharan Africa and the production of winter wheat in agroforestry systems in France.
- The use of trees as windbreaks, where trees do not stimulate crop growth like in the cases above, but where without trees crop production is difficult or impossible.

In the rich Western world, particular forms of agroforestry receive increasingly attention today: permaculture and food-forests. In their promotion and in describing their potential, the bottleneck of competition is neglected (Shepard 2013). I encountered a case where at least the economics are positive, but not thanks to tree supported crop growth but thanks to the choice of expensive nuts and berries, serving a niche market for the rich.

For the ideals that are formulated in promoting permaculture and food-forests, e.g. sustainable food production, carbon sequestration, and erosion control, niche markets are of limited interests. Agroforestry for the sake of more productive and more sustainable staples is required for large scale benefit. It is also this type of agriculture that serves food security in sub-Saharan Africa.

This paper describes such a system by presenting its history, a system that is not hindered by the bottleneck that the competition power of trees bypasses their positive influence on crop production. It does so thanks to improvement of the fertilizer use efficiency through the presence of trees.

Woody plants in agro-ecosystems of semi-arid regions

In “woody plants in agro-ecosystems of semi-arid regions”, Breman and Kessler (1995) analyze the interaction between trees and the surrounding vegetation, crops included, using the Sahel as illustration. Focusing on nutrients, water, and light, they show which tree properties through which processes cause a higher accessibility of nutrients and water than in case of herbaceous plant species alone, and they quantify the contribution of each of the processes with soil and climate as main variables. This knowledge is used to understand in which ways trees can contribute to an increased availability of nutrients and water for surrounding herbaceous plants, and how this contribution can overcome the competition for nutrients and water.

Two of the results are of direct interest for this paper:

- By far, the most important process through which trees can improve the availability of nutrients and water for crops is an indirect one, resulting from all direct processes: the improved soil organic matter status.
- The potential positive effect of trees on surrounding herbaceous plants decreases with i) decreasing soil fertility and with ii) increasingly unfavorable climatic conditions.

The latter, implies that beautiful examples of permacultures on fertile soils of the tropics, such as food-forests from Java (Indonesia), will have a much lower potential when “copied” on poor soils under low rainfall conditions at low temperatures.

The first result, serves as prelude for the rest of this paper. Combined with the second result, it implies that the positive effect of trees increases with increased soil fertility. Where without trees, the average natural availability of nitrogen (N) for herbaceous plants increases from 10 to 25 kg ha⁻¹ year⁻¹ going from the southern Sahel to the southern Soudan savanna, thanks to the presence of trees these figures become 3 to 6 kg ha⁻¹ year⁻¹ higher. The trees help avoid N losses in the order of 30% of potentially available N, thanks to improvement of the soil organic matter status. Hence, crops on land with trees receiving annual rates of 120 kg fertilizer N ha⁻¹, may be able to utilize 30 kg ha⁻¹ more than without trees. For farmers it is much more interesting to use trees to improve the efficiency of fertilizer than to use them to avoid fertilizer. In this context it is useful to know that the improved availability of nutrients with trees is more pronounced for N than for phosphorus (P). In agroforestry, P is more likely than N to be or to become a limiting factor. Consequently, fertilizing with P is most beneficial and can have synergistic effects by enhancing biological N fixation.

One has to realize, however, that this potential synergistic effect does not imply that leguminous tree species are the best to be used in agroforestry. It is more logic to benefit from it through leguminous crops. The reason is the relatively limited contribution of leguminous tree species to the improvement of the soil organic matter content, the way through which trees have the highest positive effect on crop growth. Leaves and other products of leguminous trees, thanks to their high N/C (nitrogen/carbon) ratio, have a high mineralization rate.

Other conditions for obtaining the highest positive effect of trees on crops, bypassing the negative effect of competition are:

- homogeneous distribution of trees in the field, having a maximum crown cover of 20 – 25%, as in case of tree parklands;
- limiting the effects of shade by high and relatively small crowns, crowns having a diameter not more than half the length of the tree stem;
- using trees with tap roots and / or cutting regularly the superficial roots.

From this short summary of conditions required for using trees to increase the availability of nutrients and water for the surrounding vegetation, crops included, it becomes clear that, indeed, the increase in the production of staples must be considerable for convincing poor farmers in sub-Saharan Africa to accept trees on their fields; i.e. to adopt agroforestry systems. Using trees for increased fertilizer use efficiency is more attractive to them than for avoiding fertilizer use; in fact, the fertilizer otherwise lost to the environment is transformed into higher tree production, increasing the benefit for farmers. If successful, the farmers will appreciate also the additional effect of increased sustainability of crop production.

Verification of positive influences of trees on crops

The possible positive influence of trees, creating the conditions as described, has been demonstrated in Togo over a ten-year period, which is in fact a period far too short to observe the potential effects, as soil improvement takes longer time. A 4-year old *Leucena leucocephala* alley cropping trial has been transformed into a parkland as described above, and maize has been produced with and without fertilizers. The results presented in the table below are those obtained 7 years after the transformation (Tamélokpo et al. 2007). Reasons exists why the presented results have to be considered as sub-optimal. As indicated, the period has been too short and the tree species used is a leguminous one. Also, the demonstration started as an alley cropping test, in which at least once a year the alleys have been cut. Decomposition of twigs and leaves accelerated soil improvement while controlling the negative effect of shade on maize growth. However, by cutting the above ground tree biomass, the tap roots did not develop. Rooting staid superficial.

The Table 1 presents both the maize yield and the other components of the above ground phytomass after the tenth year of trees presence. Fulfilling the conditions described in the above paragraph, trees are able to double crop yield. But even a relatively low dose of fertilizer increases crop yield more. In case of fertilizer use, the trees do not provoke an extra effect on grain yield. However, as predicted by Breman and Kessler (1995), when considering the overall above ground production, the tree effect on the overall above ground production is much higher with than without fertilizer. Fertilizer appeared to double the production of tree leaves and wood, leading to better soil improvement and higher farmer's income.

Table 1: The total above ground production of parkland agroforestry during the main growing season, without and with fertilizers, compared with a treeless control.

| Treatment | Yield (t ha ⁻¹) | | | | |
|-----------------------|-----------------------------|-------|-------------|------|-------|
| | grain | straw | tree leaves | wood | total |
| control | 1.3 | 1.9 | 0 | 0 | 3.2 |
| control + fertilizer | 4.2 | 6.3 | 0 | 0 | 10.5 |
| parkland | 2.6 | 3.9 | 5.0 | 6 | 18.5 |
| parkland + fertilizer | 4.1 | 6.1 | 9.5 | 15 | 34.7 |

Sustainable energy production through woodlots and agroforestry in the Albertine Rift

The knowledge and experience summarized in the above paragraphs was used to formulate and implement a reforestation project in the Albertine Rift financed by the Dutch development cooperation. Tree planting was done for and with farmers on farmers' fields. Farmers could make a choice between small woodlots for firewood or agroforestry, while they also could make a choice regarding the tree species used (IFDC 2012).

More than 20.000 ha were planted with farmers in 3 years, with a clear preference for woodlots. About one third of planting concerned agroforestry fields, for which farmers chose, in order of importance, mainly *Maesopsis eminii*, *Cordia Abyssinia*, and *Grevillea Robusta*.

Based on the analysis and quantification of processes through which trees interact with surrounding vegetation, taking the results of the demonstration in Togo into account, an ex-ante study was done regarding the potential benefits of agroforestry systems in Burundi, Eastern DRC and Rwanda. Two situations were distinguished: i) using trees and fertilizer to increase staple production on slopes, while stopping or diminishing soil erosion, and ii) using the same system in flat high productive valleys for increased staple and wood production. It was estimated that the net benefits for farmers at the 2012 prices are in the order of 500 and 1000 \$ ha⁻¹ year⁻¹. In the first case the benefit of crops is somewhat higher than those from trees, the opposite is observed for the second case.

Without fertilizer and trees, the average annual net benefits of extensively produced maize and beans are in the order of 350 \$ ha⁻¹. In other words, it seems possible to increase farmers benefits through trees aiming to improve fertilizer use efficiency on crops. Not included in the benefits is, among other effects, the increased sustainability of production, thanks to erosion control. It is worthwhile mentioning that another donor-supported intervention for erosion control in the region is terracing, which has extremely high investment costs: terraces would be hardly profitable using a cost-benefit analysis (Bizoza and de Graaff 2012).

Conclusion

For farmers in sub-Saharan Africa interested in agroforestry for producing staples, trees supporting the use of fertilizers should be promoted. It is also a cheap alternative for otherwise very expensive erosion control investments.

References

- Bizoza AR, de Graaff J (2012) Financial cost–benefit analysis of bench terraces in Rwanda. *Land Degrad Dev* 23: 103-115.
- Breman H, Kessler JJ (1995) Woody plants in agro-ecosystems of semi-arid regions with an emphasis on the Sahelian countries. *Advanced series in agricultural sciences* 23, Springer-Verlag, Berlin, Germany.
- IFDC (2012) SEW. Sustainable energy production through woodlots and agroforestry in the Albertine Rift. IFDC-Burundi (Bujumbura) and IFDC Headquarters. Alabama, USA.
- Shepard M (2013) Restoration agriculture. Real-world permaculture for farmers. Acres, USA.
- Tamélokpo A, Mando A, Breman H (2007) Influences des éléments manquants et la gestion du sol en agroforesterie sur les rendements de maïs et le recouvrement de N, P et K. Rapport intern, IFDC-Togo, Lomé.